

**Product Development Team
for
NEXRAD Enhancements**

Quarterly Report – 3rd Quarter FY 00

00.6.1 Damaging Winds

Development and enhancement of the Damaging Downburst Detection and Prediction Algorithm (DDPDA) to ensure that it meets the aviation communities' needs for the prediction and detection of damaging winds associated with both wet and dry atmospheric environments, along with larger scale downbursts.

a) Current efforts

The DDPDA prediction methods were finalized during the third quarter, as several changes were made to the DDPDA software to improve the calculation of many DDPDA diagnostic parameters. The software improvements should be the final changes in methodology required before DDPDA is delivered for implementation in Open Systems. DDPDA downburst prediction equations may be upgraded as needed by changing several adaptable parameters based on the statistical analysis of cases in the DDPDA database.

The DDPDA downburst events database was expanded to include 100 severe downburst events (radial wind exceeding 25 m/s or radial divergent velocity difference exceeding 40 m/s) and over 1300 null events from 38 days (approximately 264 hours of radar data). A large number of weaker downburst events are also documented in the data set.

b) Planned Efforts

Work during the fourth quarter (continued funding by the OSF) includes finalizing the DDPDA adaptable parameters and providing an evaluation of the algorithm performance.

c) Problems/Issues – none.

d) Interface with other organizations – none.

e) Activity schedule changes

Significant progress has in DDPDA development and analysis progress has been made during the 3rd quarter once the OSF MOU was finalized. Milestone 00.6.1.E1 is finished.

00.6.2 Polarization and Frequency Diversity

Continue development of algorithms that utilize polarization data to detect and predict the movement of the volumetric extent of hydrometeors such as hail, rain, snow, sleet, icing conditions, and freezing rain that are hazardous to aircraft.

a) Current Efforts

Analysis of datasets collected with NCAR's S-band polarimetric radar (S-Pol) continued. To investigate beam broadening effects on potential algorithms designating the 0°C level, examination began of vertically pointing data collected during field programs in Florida, Brazil, and Italy. Data range resolution (gate-to-gate) is 150 m. Preliminary results show radar reflectivity bright bands typically have vertical dimensions of 1 to 1.5 km. The rapid increase in reflectivity toward ground begins well before increases in linear depolarization ratio (LDR) and decreases in correlation coefficient (ρ_{hv}). The LDR and ρ_{hv} signatures are believed to signify the presence of water and appear approximately at the height of the reflectivity maximum. The signatures persist in layers 0.6 km thick. The higher altitude of the initial radar reflectivity increase is thought due to greater "stickiness" of ice particles as they "warm". The vertical pointing data were collected as part of system calibration procedures. Unfortunately, simultaneous *in-situ* measurements from aircraft are not available.

Figure 1 shows range-height (RHI) displays for a) radar reflectivity, DZ; b) linear depolarization ratio, LDR; c) differential reflectivity, ZDR; d) correlation coefficient, ρ_{hv} ; e) particle identification results, PD; and f) 2-D particle probe data (PMS) obtained by the University of North Dakota's Citation jet. The storm was observed on September 14, 1998 near Melbourne, Florida. The aircraft location is denoted by a small rectangle. The PMS images have poor resolution but show liquid drops with maximum diameters greater than 1 mm existing at -8°C. The Rosemont Icing Probe (RICE) indicated that icing was occurring (not shown). Radar observed reflectivities are 25 to 35 dBZ. Low ZDR values of 0.3-0.8 dB, LDR of <-25 dB, and ρ_{hv} close to 1.0 are all consistent with measurements dominated by small liquid drops.

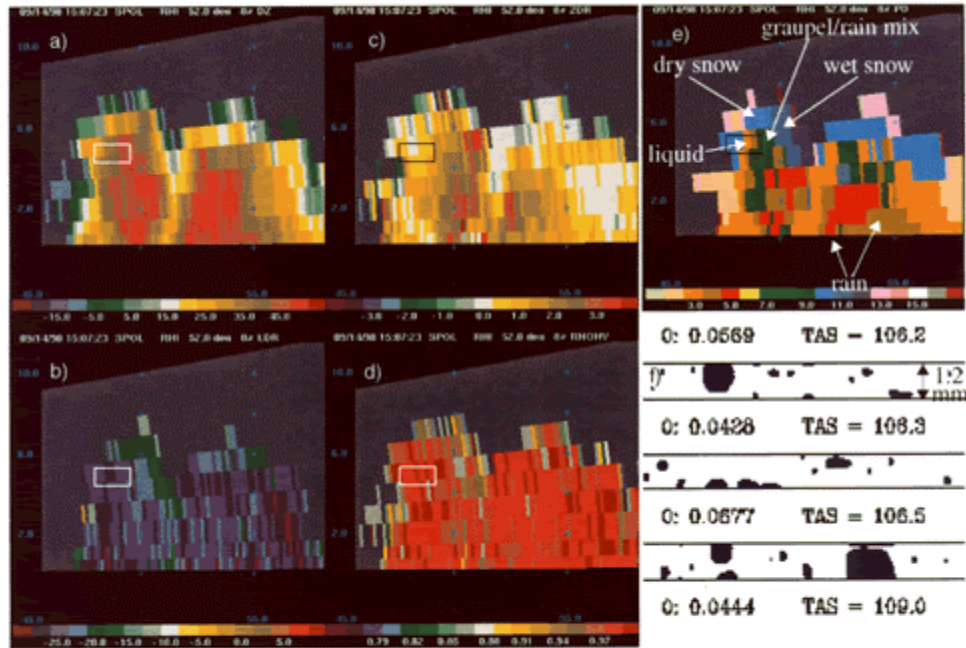


Figure 1. RHI displays of a) Z_{HH} , b) LDR, c) Z_{DR} , d) ρ_{HV} , and e) the particle classification results, along with f) a sample of the corresponding aircraft PMS data.

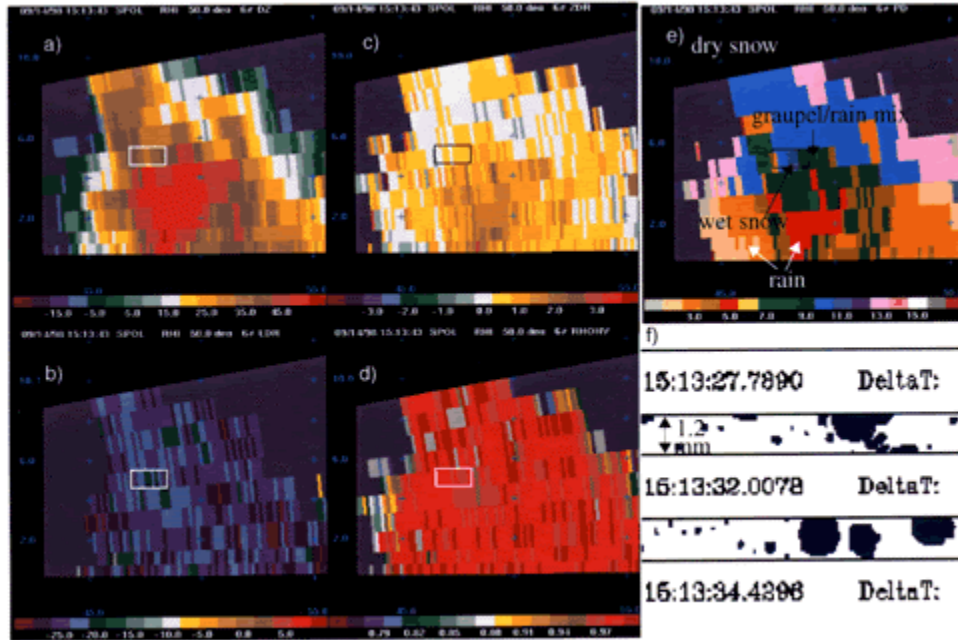


Figure 2. A similar display as Figure 1 for the same cell about 5 minutes later.

Figure 2 shows the storm ~5 minutes later. The cell has grown in height and intensified. The aircraft has climbed to an altitude with a temperature of -10°C . PMS images depict non-spherical particles with irregular edges, indicative of frozen drops or graupel. The RICE probe continued to register icing. Thus, the

frozen particles are probably undergoing riming. The polarimetric measurements suggest the aircraft is in a transition zone between dry snow aloft and mixed-phase conditions below. High LDR and low ρ_{hv} values at and just below the aircraft's level are designated as graupel mixed with rain and as wet snow.

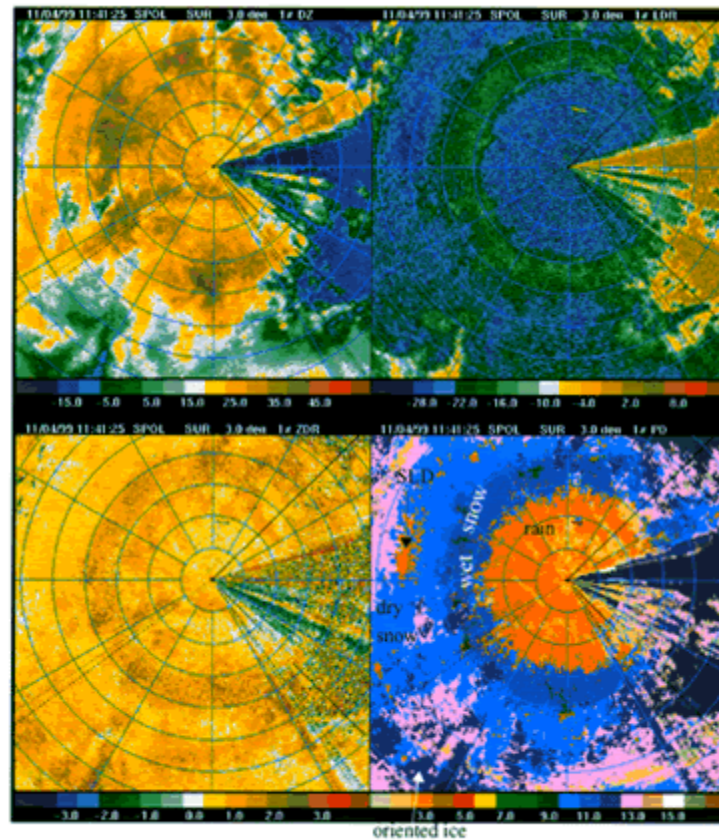
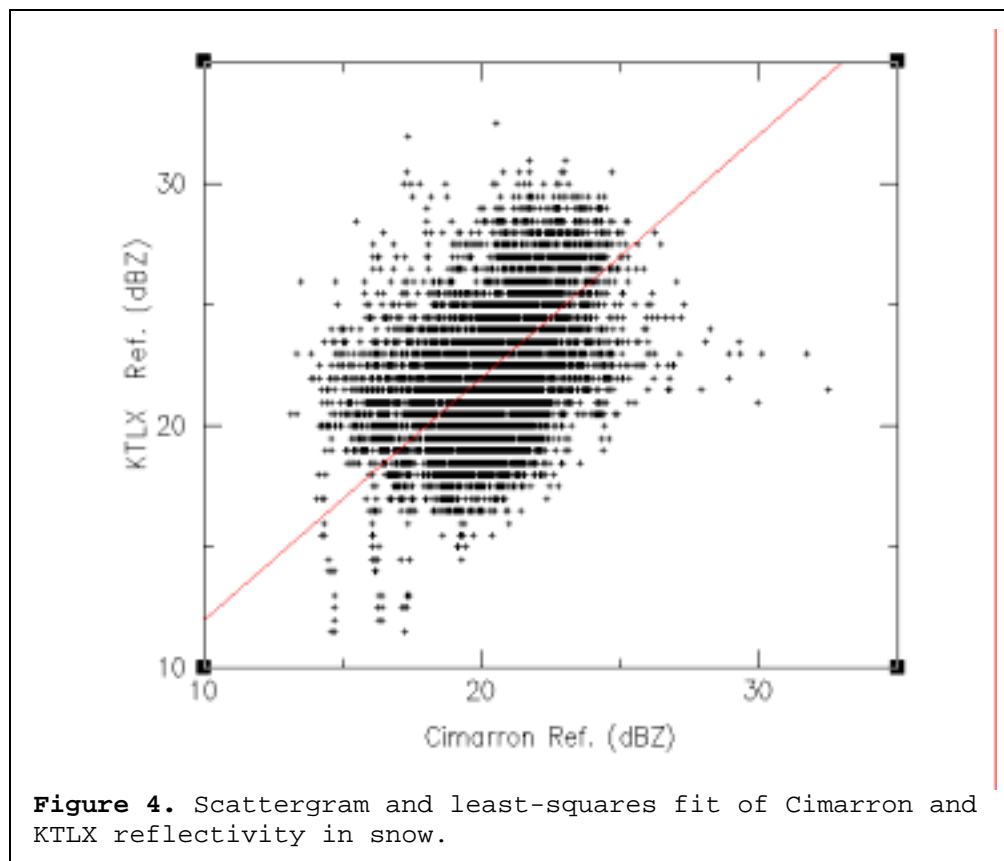


Figure 3. PPI displays of a) Z_{HH} , b) LDR, c) Z_{DR} , and d) the particle classification results.

Measurements and particle classification results from a stratiform rain case observed during MAP on November 4, 1999 are presented in Figure 3. The data are from an antenna elevation of 3°; range rings are 10 km. Significant blockage can be seen to east of the radar. The melting layer is clearly seen in the ZDR and LDR fields between 30 and 40 km range (2-2.5 km MSL). The NOAA P-3 was flying above the melting layer to the southwest of the radar. Aircraft sensors recorded snow and crystal aggregates but no icing. This agrees with the particle classification of dry snow. Notice that the LDR values average < -25 dB in the rain below the bright band and range from -22 to -25 dB in the snow layer. LDR in the melting layer is -18 to -22 dB. The particle classification successfully delineates the rain, melting snow, and dry snow layers. Oriented ice crystals are designated at far ranges to the southwest of the radar (the lower left corner of Figure 3d). This is a plausible classification in view of the low reflectivity and high ZDR at this location. There is also a region

of low LDR and high reflectivity identified as SLD to the west of the radar. Although unverified, this designation also seems reasonable given the low values of LDR, moderate reflectivity, and the high incidence of icing under similar conditions in other MAP datasets.

Software development for the calibration of Cimarron reflectivity data against KTLX WSR-88D reflectivity data is finished. Figure 4 shows an example of this calibration for a snow case. Here the correction to the Cimarron data is 2 dBZ. This correction is added on a gate-by-gate basis before further analysis of the data is performed.



The calibrated reflectivity data will be used for hydrometeor classification and rain estimation. Examination of the Cimarron snow case reveals that the hydrometeor classification algorithm can detect snow. The melting region, classified as wet snow, coincides with a minimum region of ρ_{hv} . However, it seems that detailed spatial temperature information is important to discriminate the snow from light rain. Spatial analysis of the data might be needed to deduce the detailed particle field over a horizontal plane when snow is present.

NEPDT participation in STEPS finished at the end of the 3rd quarter. Visits were made to both the S-Pol and CSU CHILL sites as well as the other operational areas. During the project several cases have been collected including a tornadic supercell case in which aircraft, ground truth, and dual-Doppler data were collected. Impressions of the performance of the Hydrometeor Classification Algorithm overall were good. One issue has been the quality of the S-Pol polarimetric data. During STEPS, the data appeared to be more robust than collected previously. There are, however, some errors in the measurements at the boundaries of clouds in low reflectivity regions. These are caused by a known beam mis-match problem.

Another key activity during the quarter was the preparation of a paper entitled "Aircraft Icing Detection Using S-Band Polarization Radar Measurements" by Ellis, Vivekanandan, Brandes, Stith, and Keeler for presentation at the 9th Conference on Aviation, Range, and Aerospace Meteorology. Data from two aircraft penetrations of a growing cumulus observed near Melbourne, Florida during the PRECIP98 project and a stratiform precipitation case observed in northern Italy during the MAP field program were analyzed.

Finally, two formal papers on polarization accomplishments are pending. The first, accepted for publication in the Journal of Applied Meteorology is entitled "Bulk hydrometeor classification and quantification using polarimetric radar data: Synthesis of relations" by Straka, Zrnica, and Ryzhkov presents tables and boundaries in two-dimensional space of various polarimetric variables which can be used in classification schemes (fuzzy logic and others). A second paper has been submitted to the Journal of Atmospheric and Oceanic Technology. It is entitled "Testing a procedure for automatic classification of hydrometeor types" by Zrnica, Ryzhkov, Straka, Liu, and Vivekanandan. In it a self-consistency test of the algorithm is developed along with publication of the previous sensitivity testing finished last quarter. Drafts of these papers are attached to this report.

b) Planned Efforts

Data analysis efforts will continue through the next quarter. Additionally a Joint Polarization Experiment (JPOLE) planning meeting is set for July 18th. Results of this meeting will be discussed in upcoming NEPDT reports.

c) Problems/Issues – none.

d) Interface with other organizations – none.

e) Activity schedule changes

The development of the findings in the two formal papers completes Milestone 00.6.2.2E1. The milestones related to the STEPS data collection efforts, 00.6.2.3E1, 00.6.2.4E1, and 00.6.2.5E1 are also finished.

00.6.3 Circulations

Continue to enhance NSSL's Mesocyclone Detection and Tornado Detection Algorithms (MDA, TDA) while developing in parallel a new algorithm which combines MDA and TDA into one algorithm which detects and analyzes all circulations - the Vortex Detection and Diagnosis Algorithm (VDDA).

a) Current efforts

i) MDA implementation into ORPG

The MDA software cleanup and technique finalization is nearing completion, and the code will be delivered to the OSF in the early part of the 4th quarter. NSSL is also completing its evaluation of the MDA performance on a database of 43-events, containing over 250 tornadoes and 2700 volume scans of data. Comparisons will be made amongst the various MDA diagnostic parameters (such as the 3D Strength Rank, Mesocyclone Strength Index, the Mesocyclone Rule Base, and the Neural Network output). Comparisons to the baseline WSR-88D Mesocyclone Algorithm will be made using two different adaptable parameter sets. Results will be reported in an OSF deliverable.

ii) MDA/TDA Database

The new suite of students that have been hired under separate funding to greatly expand the MDA database for the development of statistics for NWS Tornado Warning Guidance have analyzed 12 new cases during the 3rd quarter. These cases represent a variety of storm types and have geographic diversity. These database efforts will be shared in the development of circulation detection algorithms for the FAA. We anticipate about 38 new cases to be added in the 4th quarter. Many of the more interesting cases in the database are given an individual analysis on the following Web page:

www.nssl.noaa.gov/teams/swat/Cases/cases_pix.html

NSSL is continuing the effort to develop a Web-based method to truth and evaluate the MDA and TDA. This will include extensive documentation and downloadable software such that NWSFO field users of the algorithms can use to develop databases similar to those developed at NSSL and add to a much larger nationwide database. We expect to release a beta version of the Web-case software in the 4th quarter. This software will be tested by NWS meteorologists at St. Louis MO, Goodland KS, and Wilmington OH.

b) Planned efforts

NSSL will present a MDA decision briefing to the NEXRAD Technical Advisory Committee (TAC) on August 22. As part of the briefing, NSSL developed a briefing package to be delivered to the TAC members prior to the TAC meeting. Results of the scoring evaluation will also be presented. NSSL

anticipates MDA will be accepted for the next feasible ORPG build (most likely Build 3, slated for Sept 2002). Near-term efforts will be focused on the implementation of MDA within ORPG.

When VDDA work continues it is intended to develop alternate and more-robust methods to store and manage the extremely large datasets output by the simulated vortex and least-squares derivative programs.

More cases are expected to be added to the database, either by NSSL, or included from future NWSFO field office local studies. Scores of the 88D-Meso algorithm using both the fielded default adaptable parameter set and the "low-threshold" parameter set will be completed next quarter.

c) Problems/Issues – none.

d) Interface with other organizations – none.

e) Activity schedule changes

MDA finalization has not proceeded as rapidly as expected. Milestone 00.6.3.E1 was to be accomplished 3 months after OSF acceptance of MDA. It will be met before the end of the fiscal year. We request this milestone be moved to 30 Sept 00.

00.6.4 Technical Facilitation

Continue to work through the process of algorithm transition to the operational WSR-88D system. This also includes development of a Common Operations Development Environment (CODE) and Application Programmer Interfaces (APIs) for a more rapid integration of algorithms into the operational system.

a) Current efforts

CODE 1.0 was delivered to the OSF during May. The OSF has been working with the CODE development team on software and documentation issues. Preliminary requirements for CODE 2.0 have been defined. Further software enhancements to CODE have continued. The looping capability within the CODE display system has been re-designed in a drag-and-drop format for loop setups. Mappings have been added in the form of GIS based "shapefiles" and the ability to read composites of reflectivity from multiple radars has been developed. Other additions to CODE during the 3rd quarter include a new version of the Severe Storms Analysis Package (SSAP). This is the package that drives several meteorological algorithms. Finally, a number of real-time CODE problems are being resolved through the prototype system at the Salt River Project in Phoenix.

The CODE 2.0 requirements currently include:

- 1) "Fly-through" cross sections of three-dimensional data
- 2) Several additional ORPG products
- 3) Terrain prototype
- 4) Enhanced algorithm testing
- 5) Rapid update ability
- 6) Event notification between machines of different platforms

b) Planned efforts

The remaining FY00 efforts will be directed to CODE 2.0 development. It will also be devoted to working on CODE 1.0 with the OSF on documentation and enhancement.

c) Problems/Issues – none.

d) Interface with other organizations – none.

e) Activity schedule changes

The delivery of CODE 1.0 and the development of CODE 2.0 requirements finishes Milestones 00.6.4.E1, 00.6.4.E2, and 00.6.4.E3.

00.6.6 Rapid Update

Develop software that produces algorithm output after each tilt, thus providing immediate information to the users.

a) Current efforts

Rapid update development started during the 3rd quarter. The necessary software to perform the rapid up has been implemented within CODE and is being tested. Initial results show all software is working with the exception of some CODE display capabilities. Once the display problems are resolved, rapid update testing and development will continue.

b) Planned efforts

Real-time rapid update implementation will be examined during the 4th quarter. It is expected a number of issues will need to be solved for real-time implementation.

c) Problems/Issues – none.

d) Interface with other organizations - none.

e) Activity Schedule Changes

Milestone 00.6.6.E1 should be met by July 31st and will be included in the monthly report. Depending on the real-time implementation issues, Milestone 00.6.6.E2 may still be able to be met.

00.6.7 Cell and Area Tracking

Integration of the Storm Cell Identification and Tracking (SCIT), the Correlation Tracking (CT) and Scale Separation (SS) algorithms into a single multi-scale precipitation tracking and forecast package.

a) Current efforts

Work during the 3rd quarter continued examination of the differences between the NSSL and MIT/LL implementation of SS/CT. NSSL implemented the MIT/LL bilinear interpolation method and NSSL's results were re-scored. The results showed little difference from those presented in the 2nd quarterly report. Differences between the NSSL and MIT/LL versions of SS/CT were assumed to be due to differences in the advection routines in both versions.

New software for SS/CT, also known as the Growth and Decay Tracker (GDT) was received from MIT/LL. The new software was requested to update the advection routines that NSSL has been using in their version of GDT. Since a complete, improved version of GDT was received, NSSL made a decision to use the new version instead of replacing the advection scheme in the previous NSSL version.

Once the new GDT code was received, NSSL tried to compile the software in a Solaris environment. Several of the libraries included with the GDT code were not compatible with Solaris and had to be recompiled at MIT/LL and sent to NSSL again. Once these new libraries were received, more problems were encountered due to compiler incompatibilities. MIT/LL is recompiling the libraries using an updated version of the GNU C++ compiler and will make these newly compiled libraries available to NSSL.

b) Planned efforts

The goal for July will be to implement the new GDT on NSSL's Sun platform. Once implemented, work will begin on software development to translate Level-II data into a compatible GDT Cartesian format. Once finished, testing and enhancement of the GDT will resume.

c) Problems/Issues – none.

d) Interface with other organizations – none.

e) Activity schedule changes

Once the libraries are acquired from MIT/LL and the software is compiled on the NSSL system, Milestone 00.6.7.1E1 will be finished. At this point it does not appear a real-time implementation test of GDT is possible before the end of FY00. The GDT I/O format is new and it will take significant software development to implement it within the CODE infrastructure.

00.6.9 Composite Products

Develop high resolution radar layer products that are rapidly updated.

a) Current efforts

Activities for the third quarter included testing the three-dimensional radar data gridding scheme for a DFW hailstorm case and expanding the scheme to incorporate additional radars.

The radar mosaic scheme has been used to mosaic 5 radars data from the May 5-6, 1995 Dallas hailstorm case. Most of the results are described in the task 00.6.14. An additional product from the 3D mosaic is the height field associated with the composite reflectivity. This field indicates the height of the maximum reflectivity in each grid column. Figure 1a shows a composite reflectivity field while Figure 1b provides the associated height field. By comparing the two figures, it is evident that near the storm cell cores, the maximum reflectivities were obtained from the lower levels, while at the edges of the echoes, the maximum reflectivities were from high levels, indicating the anvil region of the convective complex. We have expanded the software scheme to mosaic up to 10 individual radars. The mosaic software is running in real time within the CODE system deployed at the Salt River Project in Phoenix. This system is generating a 1-km resolution mosaic with 20 vertical levels every five minutes using 6 radars.

A sample data set of three dimensional reflectivity data was provided to Mitre. Software was developed to unpack the data and to convert it to the standard 1 nmi mosaic used in the en-route air traffic control system. A prototype of the en-route controllers' Display System Replacement (DSR) situation display has been modified to display a controller-selected altitude strata of the reflectivity data along with recorded air traffic control data.

Descriptions of the bright-band identification and clutter/AP removal algorithms used in the generation of the reflectivity fields are attached to this report.

b) Planned efforts

The main focus during the next quarter will be to continue testing of the 3-D radar mosaic analysis scheme. Testing of the scheme using a winter storm and summer case will begin and the current scheme extended to handle up to 8 radars.

In the next quarter, echo top data will be derived from the gridded reflectivity data and displayed on the controller's display. A stand-alone display demonstration package will be prepared for NSSL's use, and the final report generated.

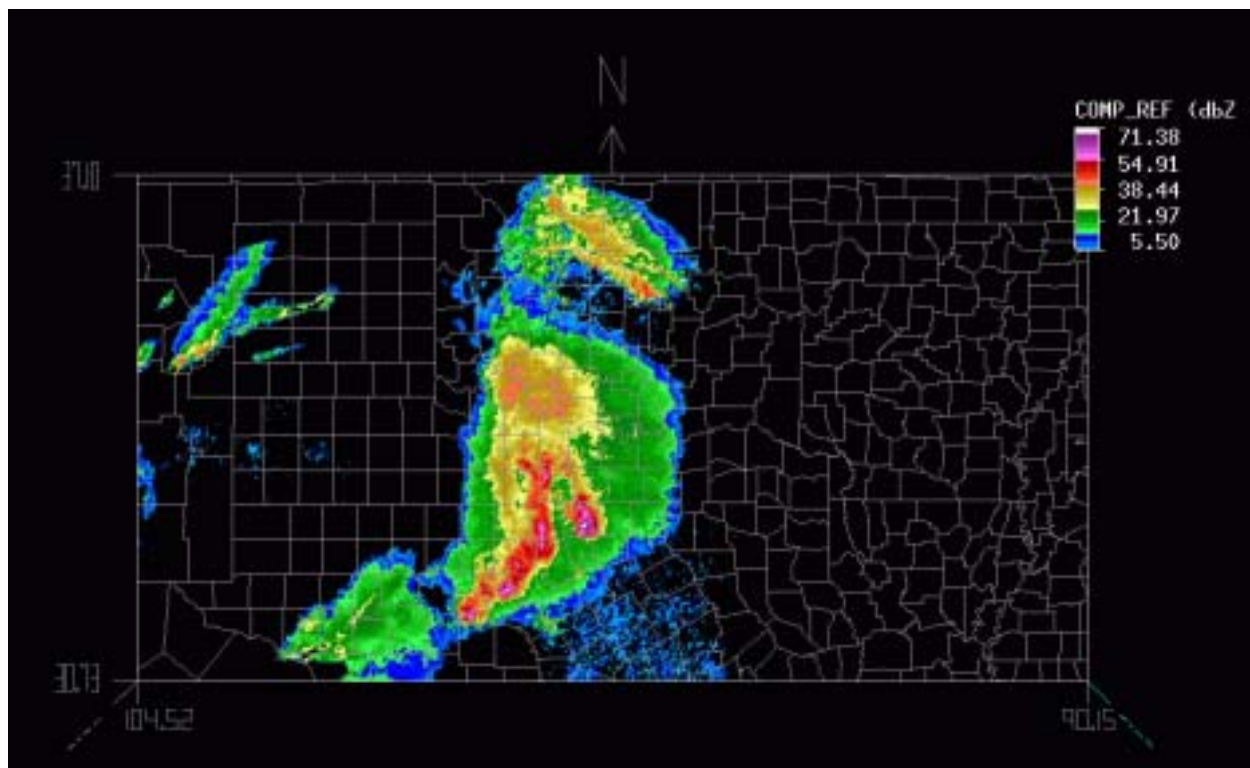


Figure 1a - Composite reflectivity field derived from the 3D-reflectivity mosaic. The data were from 5 WSR-88Ds (KDYX, KFWS, KGRK, KLBB, and KTLX)

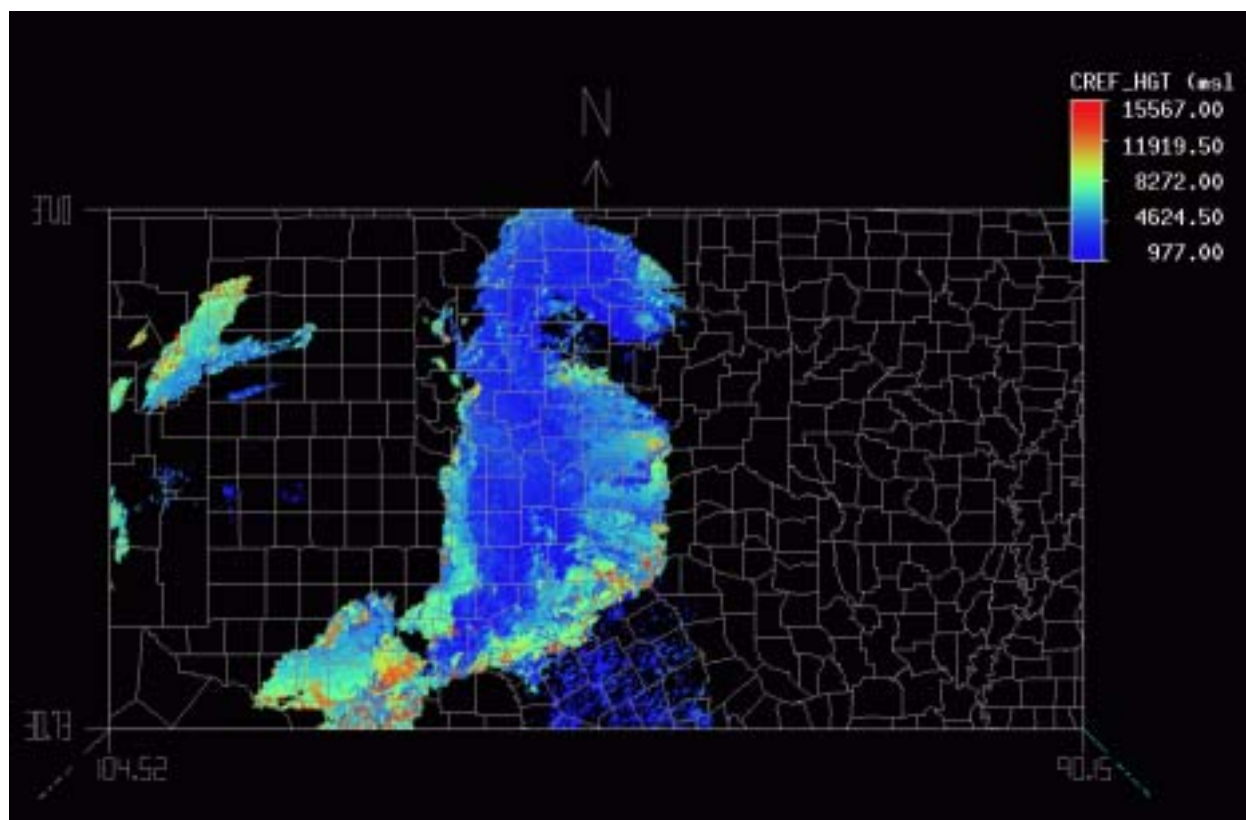


Figure 1b - The height associated with the composite reflectivity field shown in Fig.1a.

- c) Problems/Issues – none.
- d) Interface with other organizations - none
- e) Activity schedule changes

The attached reports satisfy Milestones 00.6.9.E2, 00.6.9.E3, 00.6.9.E4. The remaining tasks are on time.

00.6.11 Volume Coverage Patterns

Develop and implement Volume Coverage Patterns (VCPs) relevant to the goals of the AWR PDTs.

a) Current efforts

Data have been collected with the new VCPs for 9 events using the OSF testbed WSR-88D (KCRI). The new VCPs have been finalized. While there is still further experimentation and analysis on how the kinematic algorithms perform using these new data, the general data collection strategies are finished.

b) Planned efforts – none for FY00

- c) Problems/Issues – none.
- d) Interface with other organizations – none.

e) Activity schedule changes

With the VCP designed finished, Milestone 00.6.11.1E1 is complete.

00.6.12 Product Implementation

Explore and define implementation paths within the aviation community systems that are best for NEXRAD PDT products.

a) Current efforts

No work has been expended on this effort.

b) Planned efforts

Travel will be planned during the 4th quarter to accomplish the goals of this task.

- c) Problems/Issues – none.
- d) Interface with other organizations – none.
- e) Activity schedule changes – none.

00.6.14 Multi-radar Composites

Develop a vision for FAA use of high resolution, rapid update, composite products which are produced from the integration of multiple WSR-88Ds.

a) Current efforts

Activities for the 3rd quarter of multi-radar composites included conversion of the Level-II data for the May 5-6, 1995 Dallas hailstorm case to product data files and the construction of a seamless mosaic of the reflectivity field. By the end of the 3rd quarter, all level-II data (from 8 radars covering the FTW ARTCC, see Table 1 in the 2nd quarter report) have been processed.

The scheme described in the 2nd quarter report for the task 00.6.8 was used to construct the reflectivity mosaic. Reflectivity mosaic fields using 5 radars (KDYX, KFWS, KGRK, KLBB, KTLX) have been completed and are shown in Figures 1-3. Figures 1a-1e show the composite reflectivity from each individual radars, with figure 2 depicting a composite reflectivity from the mosaic field. The composite reflectivity fields were valid at 23:30Z on May 5, 1995. The mosaiced field provides a more complete view of the storm complex over the individual radar composite reflectivity fields.

Various 3D renderings of the mosaiced reflectivity field were constructed using the Vis5D software developed at the SSEC (Space Science and Engineering Center) of the University of Wisconsin (<http://www.ssec.wisc.edu/~billh/vis5d.html>). A series of horizontal cross-sections of the mosaiced reflectivity field are shown in figure 3 along and vertical cross sections shown in figure 4. Examining figure 3 it is evident that the radars provide only limited coverage at the lowest levels (Figs. 3a and 3b) since the base elevation angle for the operational WSR-88Ds is 0.5 degrees. The mosaic scheme does not interpolate radar information below the lowest radar tilt since there is no physical basis for the extrapolation to ground level. Figure 4 depicts the vertical core structure and intensities of several cells each with various vertical extents. These limited examples show that the construction of 3D mosaics from multiple radars can provide a very useful diagnostic tool for forecasters to examine storm structure and possible evolution.

b) Planned efforts

Efforts for the remainder of FY00 include finishing the composites for the remaining radars covering the hailstorm case. Additionally, a multi-radar working group meeting is being planned for August 21st or 24th.

c) Problems/Issues – none.

d) Interface with other organizations – none.

e) Activity schedule changes

Because the multi-radar meeting has not yet been held, it is requested that Deliverable 00.6.14.E1 be moved to September 30th.

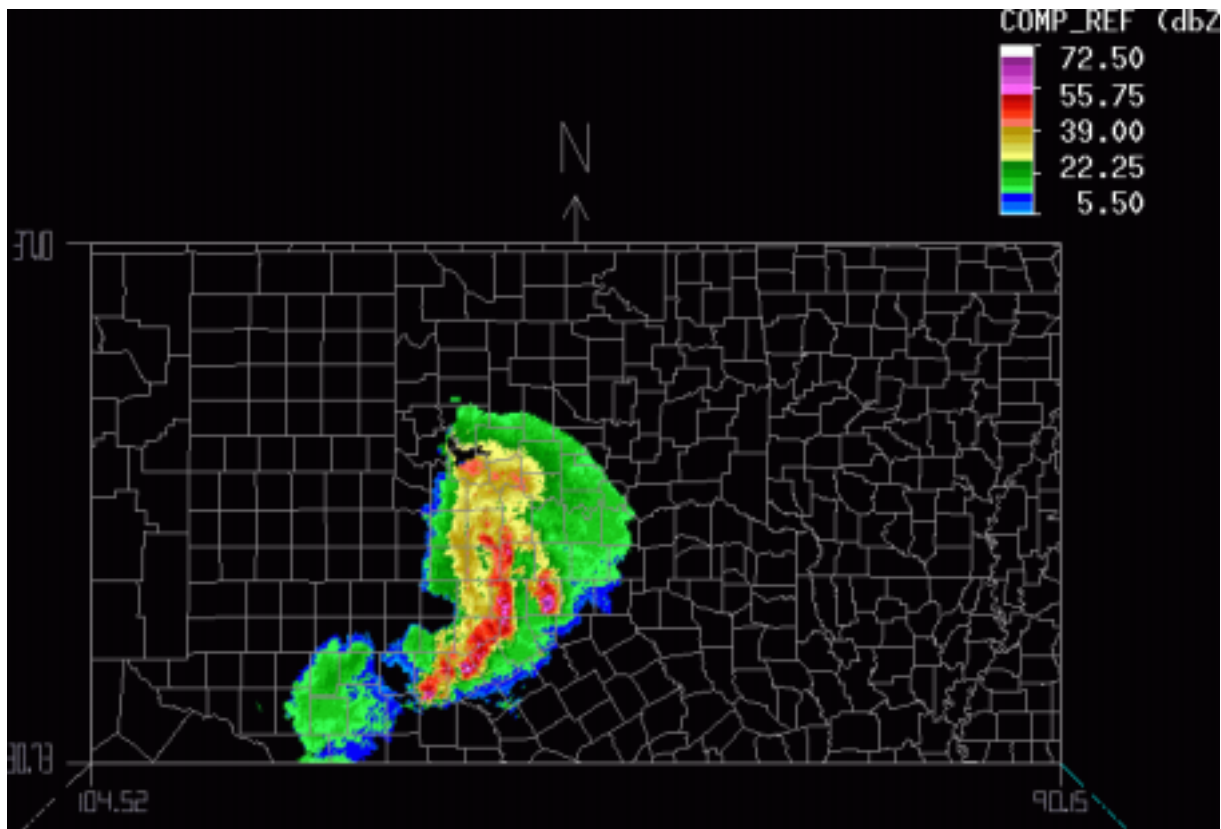


Fig.1a The composite reflectivity field from KDAY at 23:30Z on May 5, 1995.

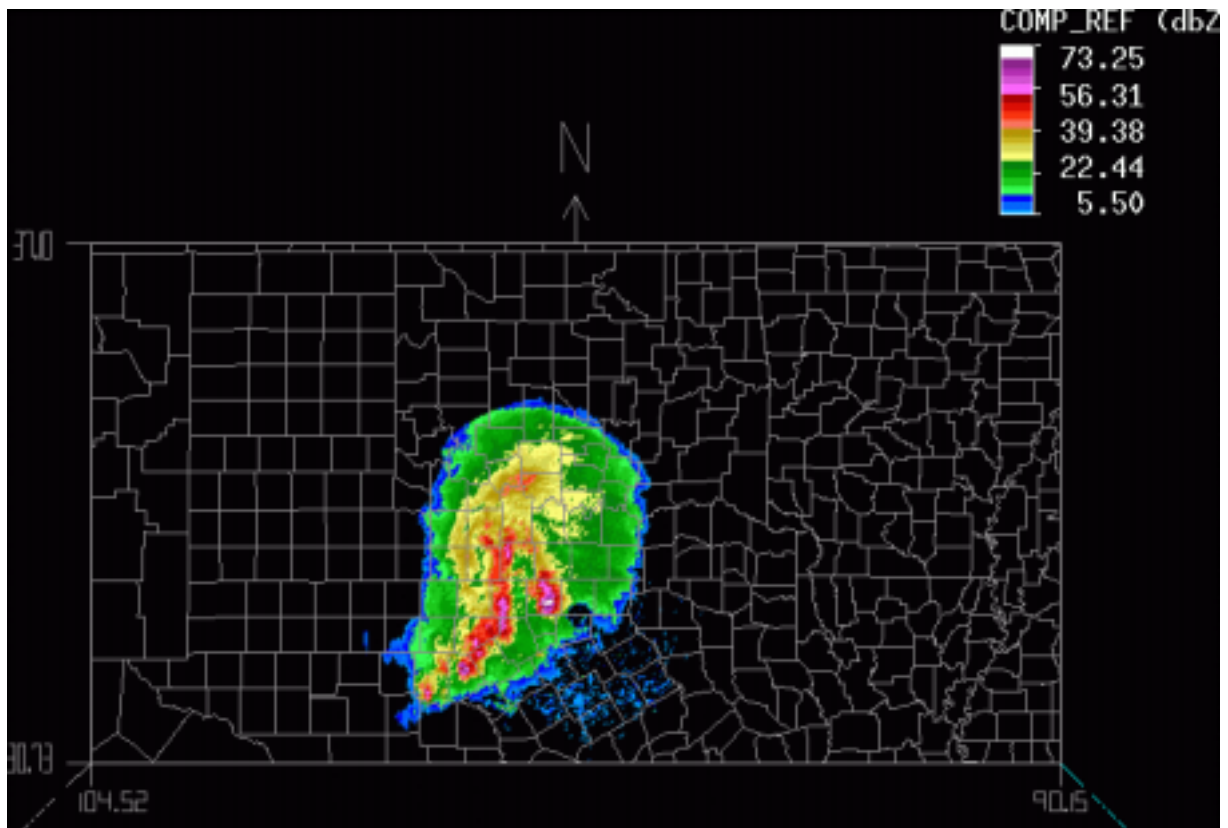


Fig.1b Same as Fig.1a except for KFWS.

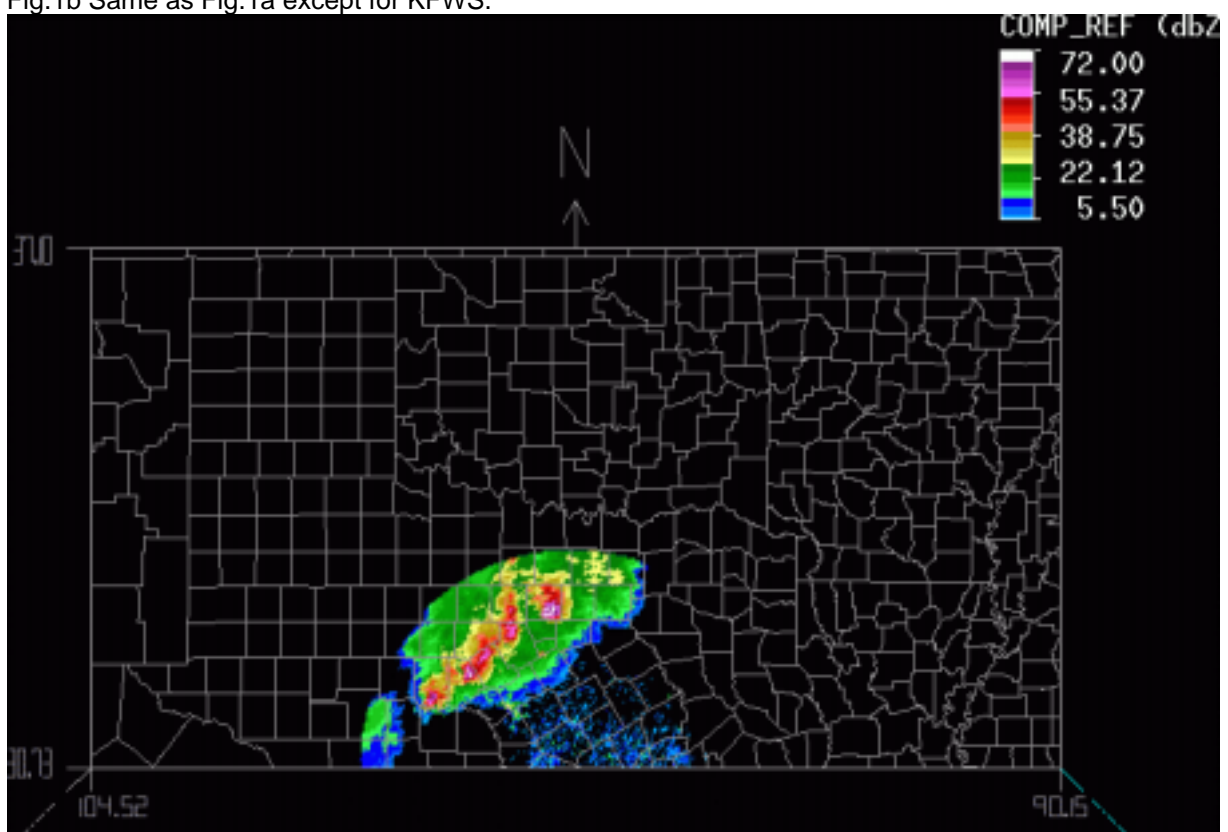


Fig.1c Same as Fig.1a except for KGRK.

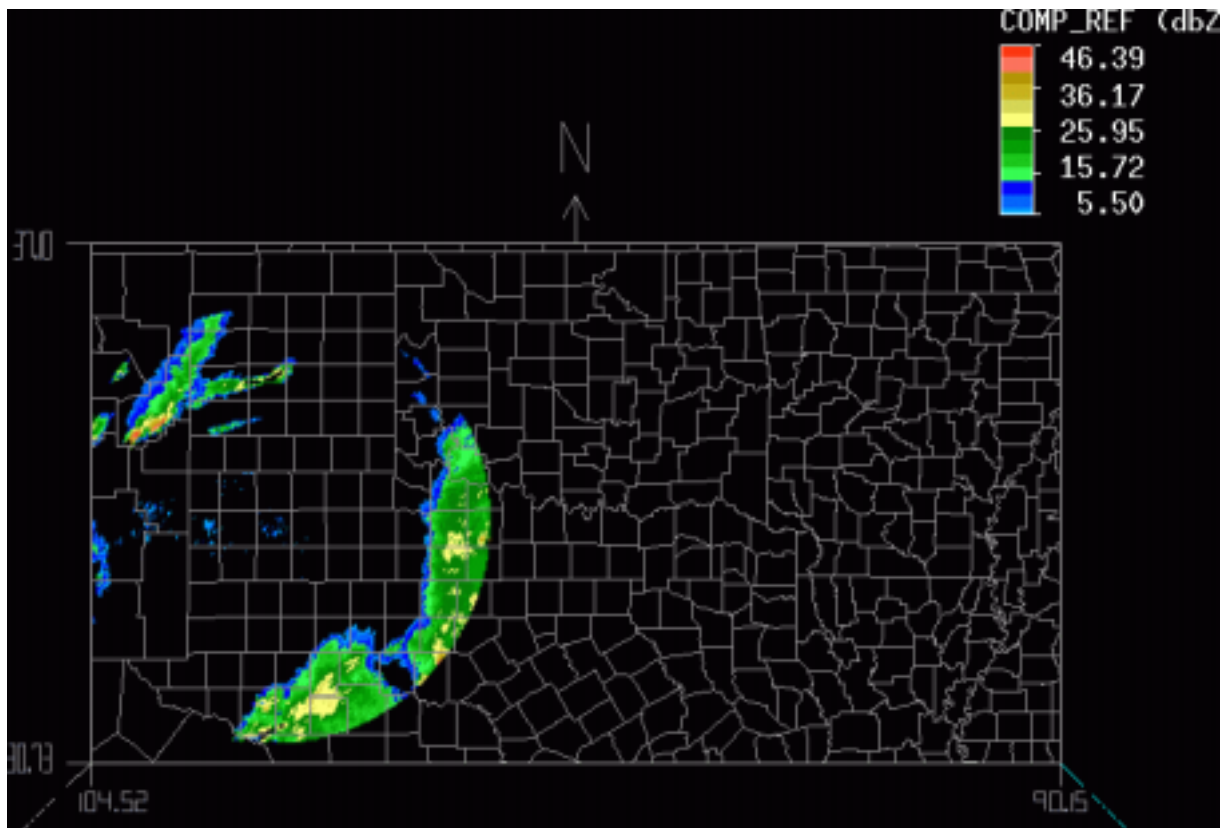


Fig.1d Same as Fig.1a except for KLBB.

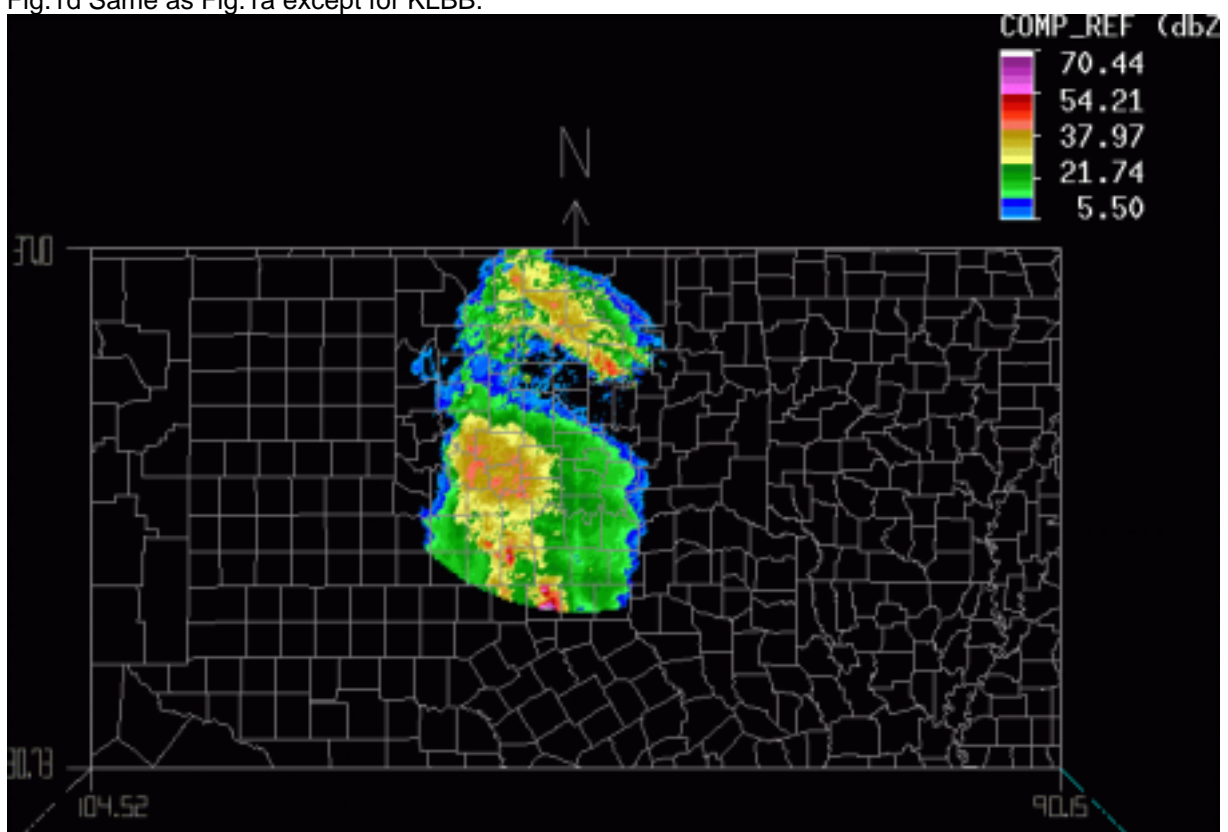


Fig.1e Same as Fig.1a except for KTLX.

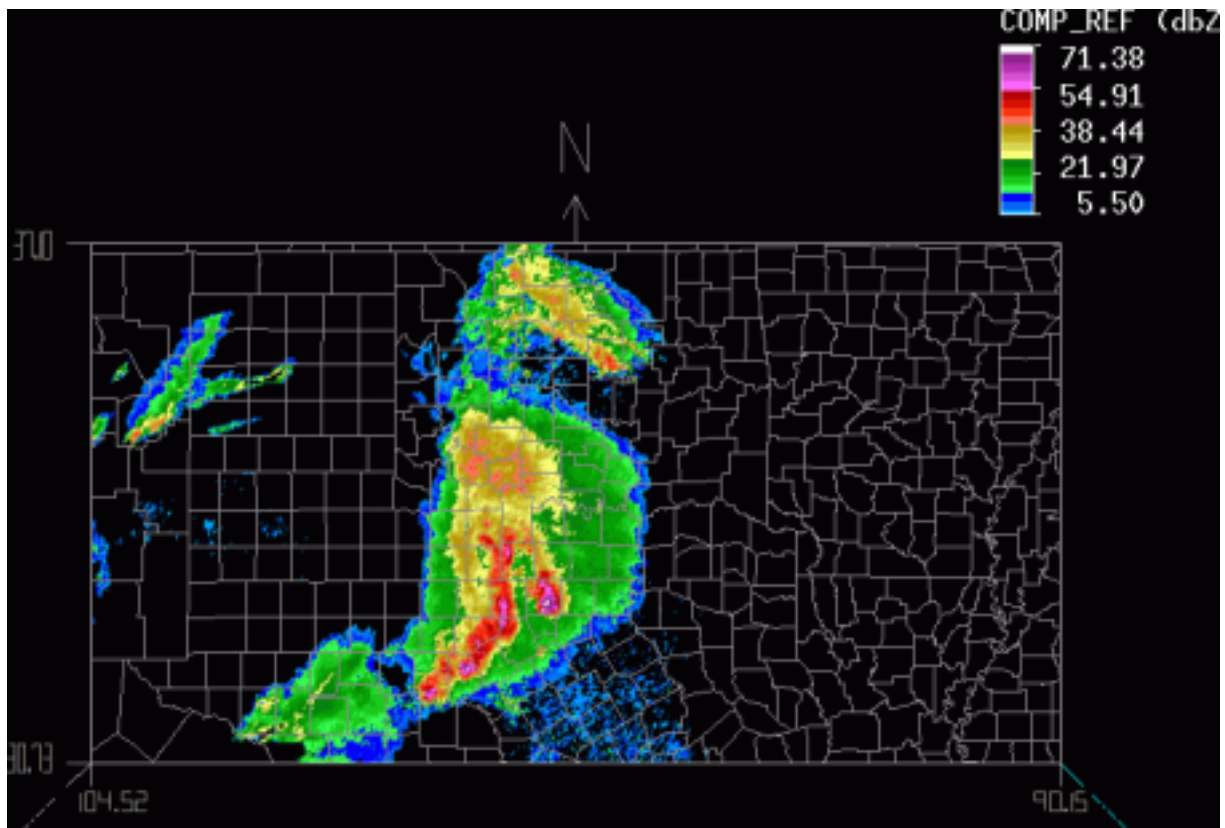


Fig.2 The composite reflectivity field from the 3D-reflectivity mosaic using all 5 radars.

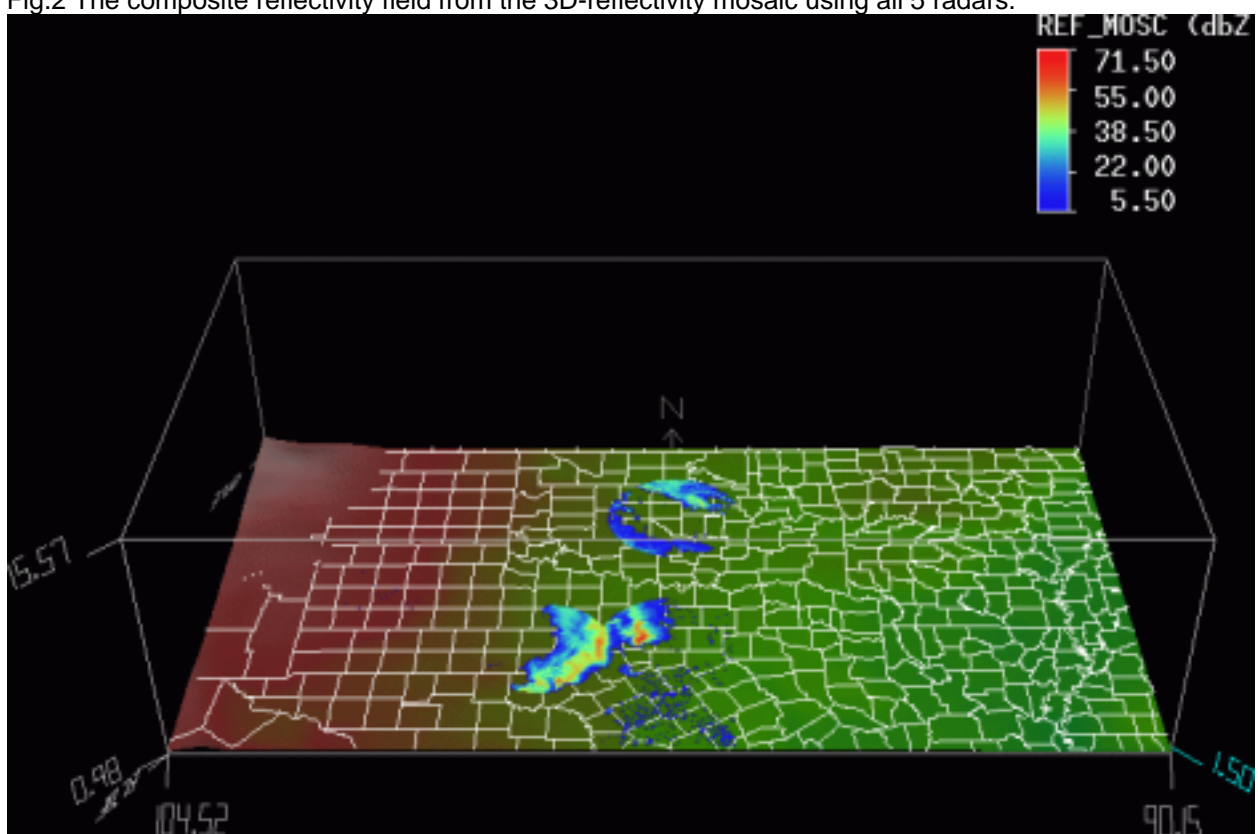


Fig.3a A horizontal cross section at 1.5km (msl) of the 3D-reflectivity mosaic.

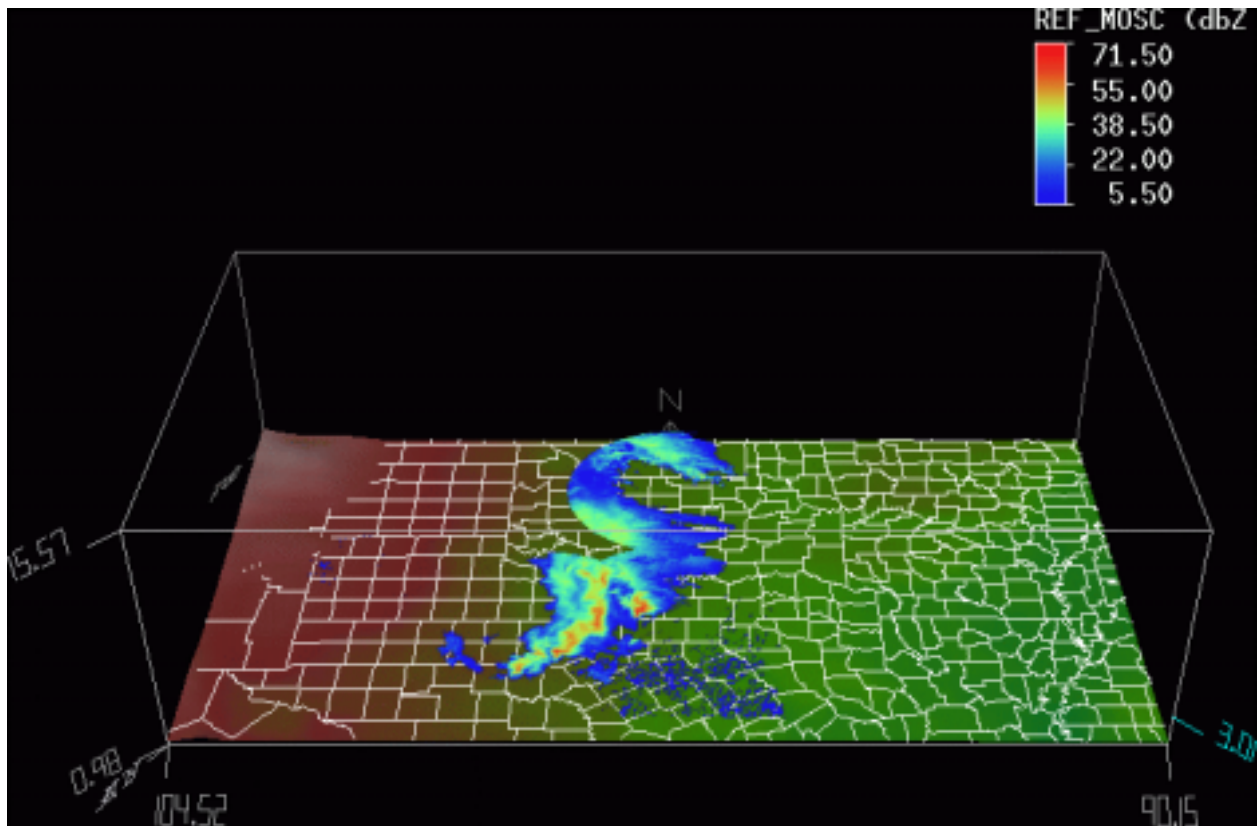


Fig.3b Same as Fig.3a except for at 3km (msl).

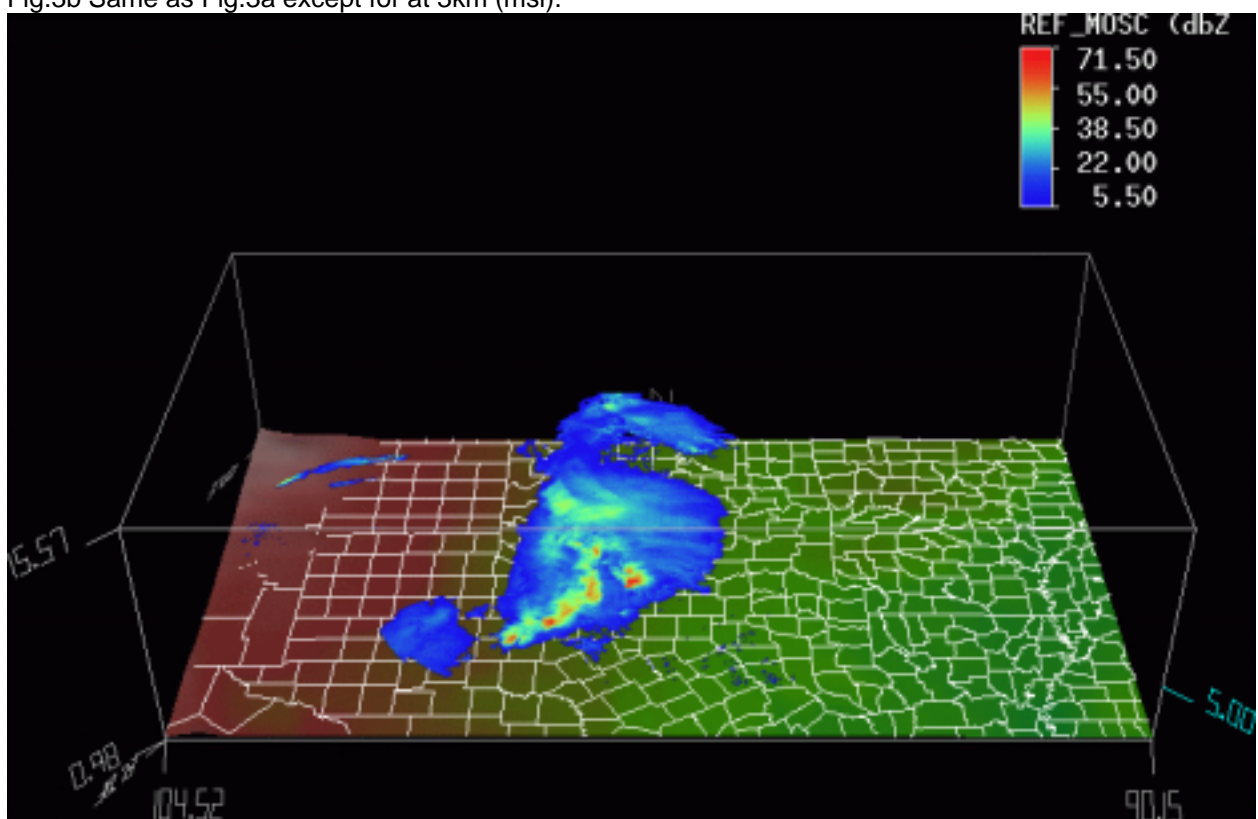


Fig.3c Same as Fig.3a except for at 5km (msl).

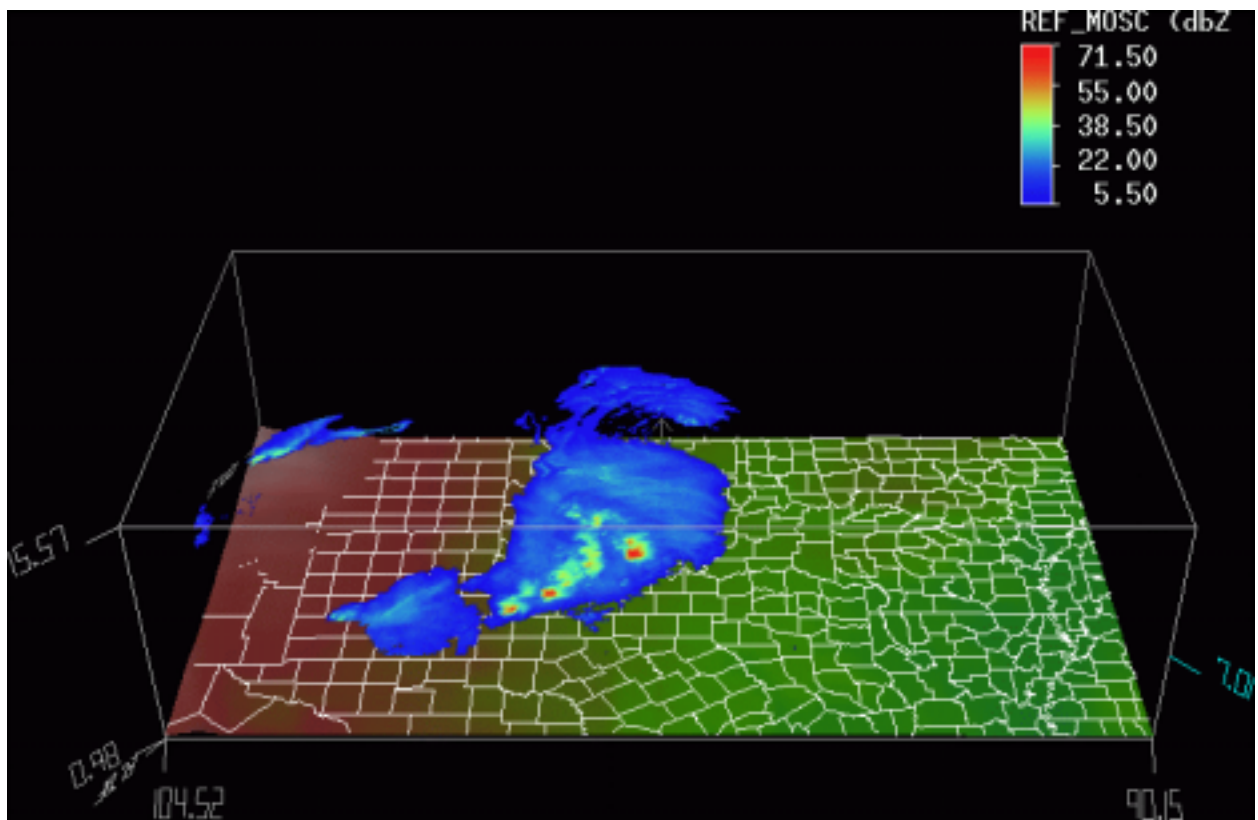


Fig.3d Same as Fig.3a except for at 7km (msl).

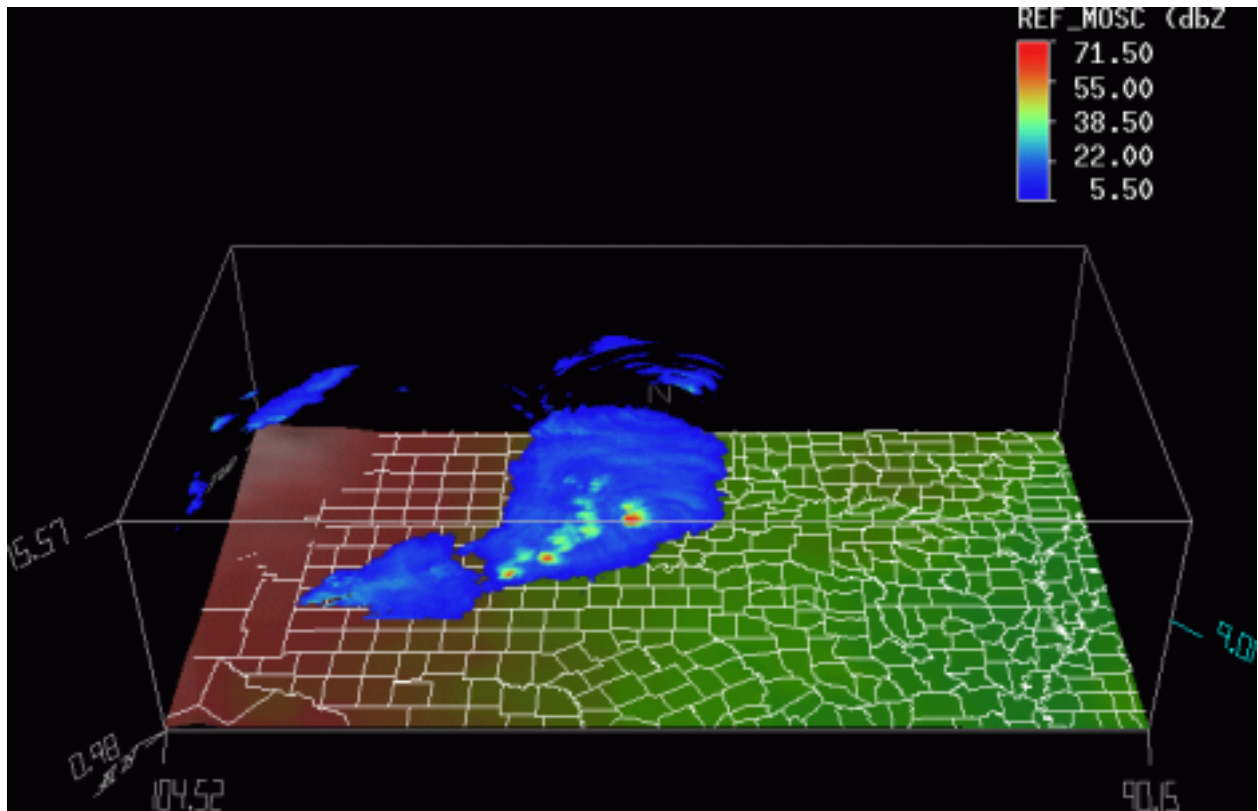


Fig.3e Same as Fig.3a except for at 9km (msl).

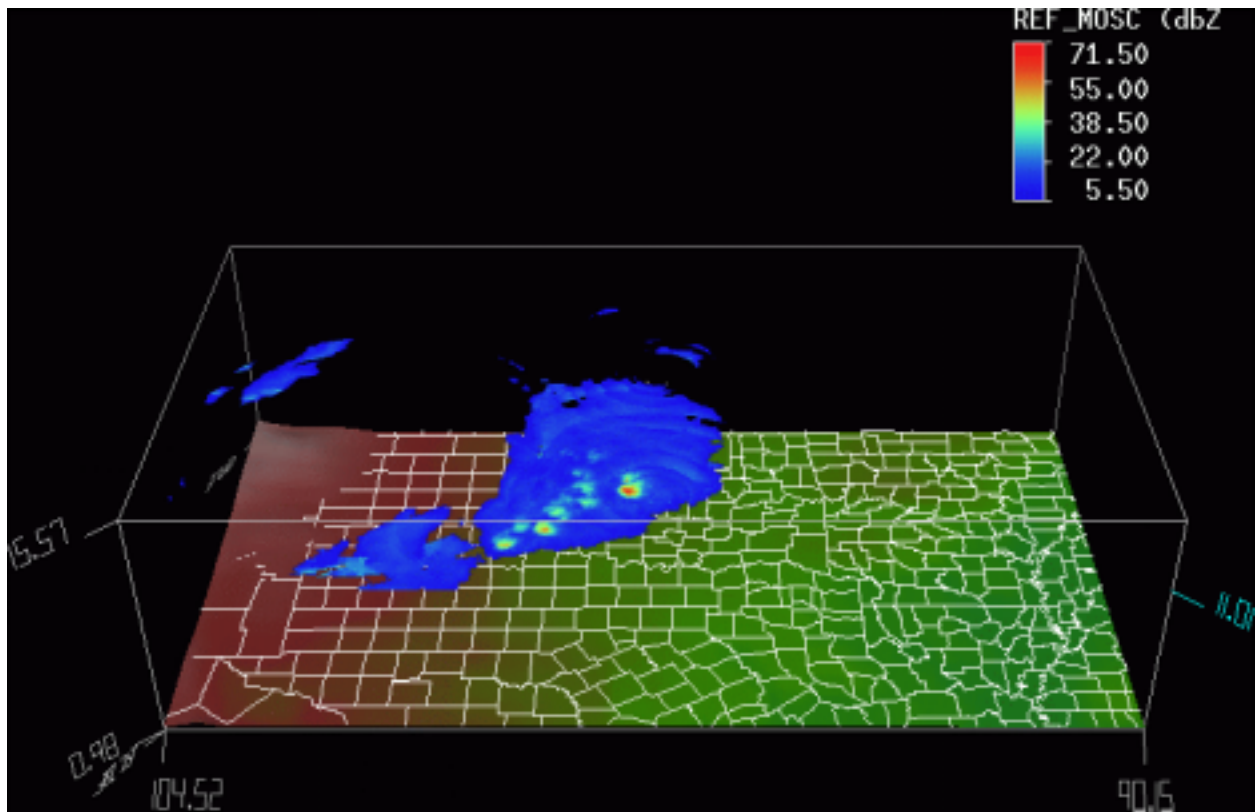


Fig.3f Same as Fig.3a except for at 11km (msl).

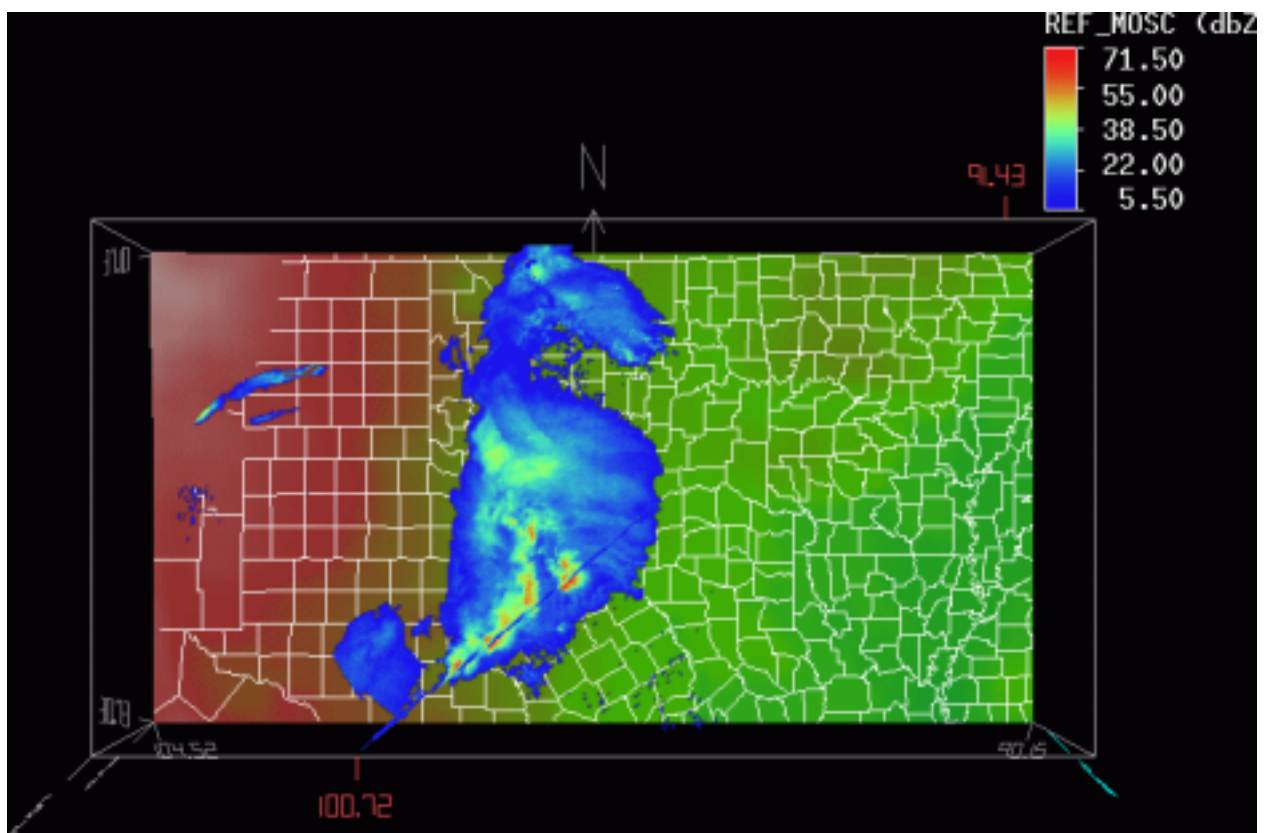


Fig.4a A top view of a horizontal cross section (at 5km msl) of the 3D-reflectivity mosaic. The two red tick marks indicate the two ends of a SW-NE oriented line along which a vertical cross-section was taken.

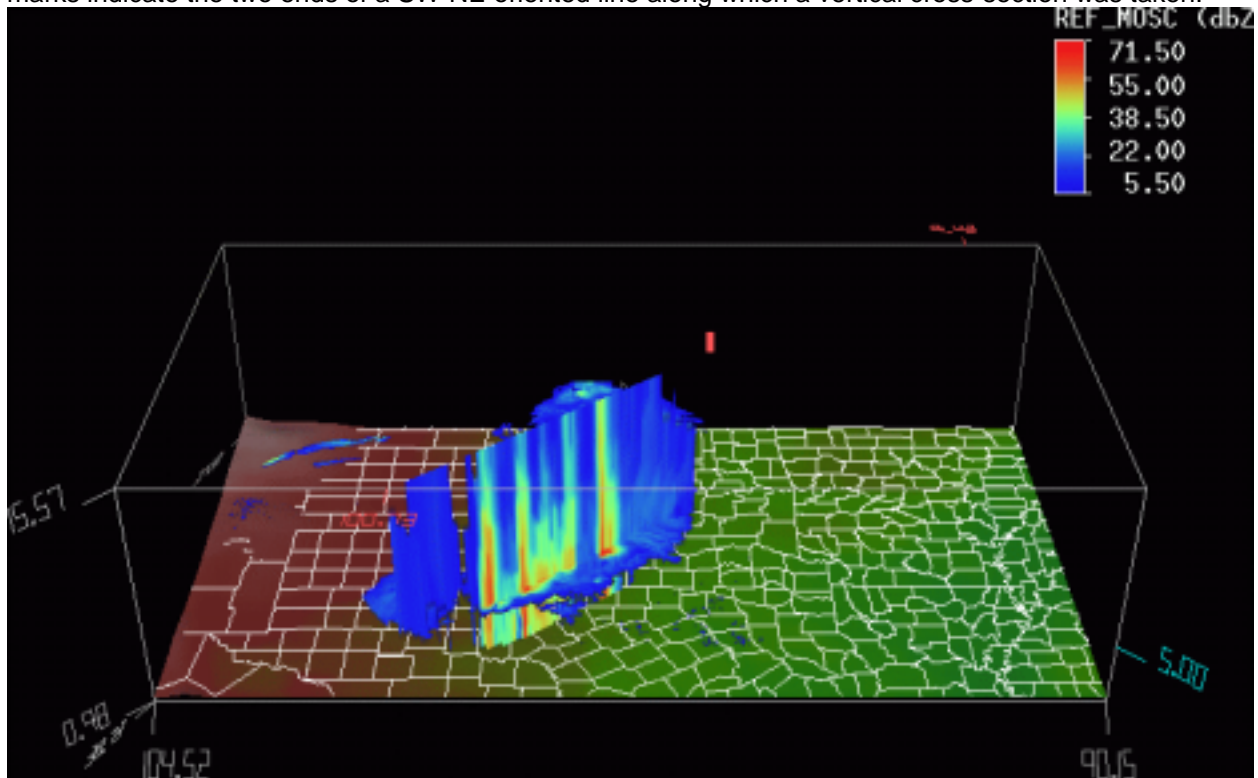


Fig.4b A view of the vertical cross section from the south.

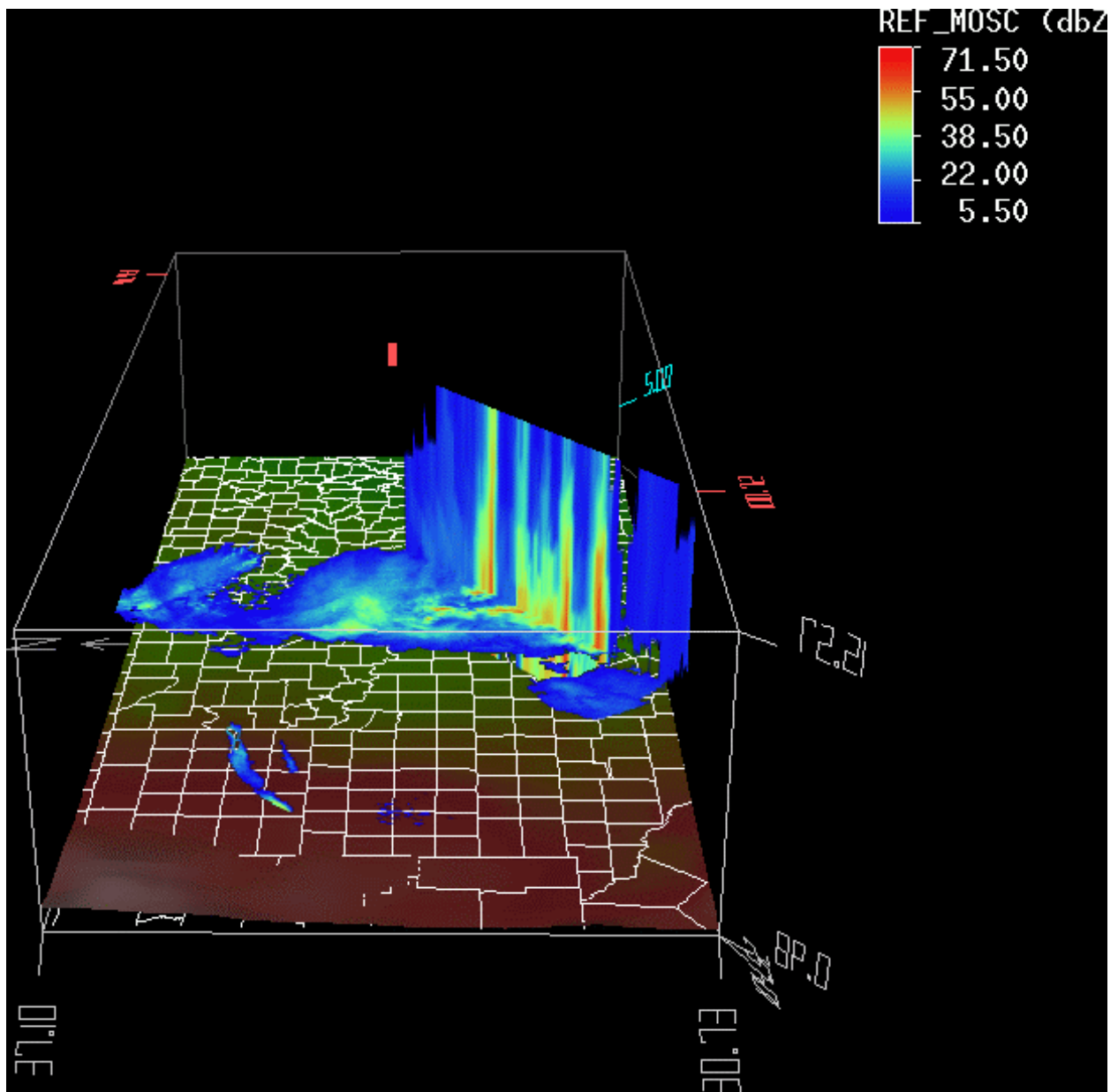


Fig.4c A view of the vertical cross section from the west.